What is the hottest burning thermite and why is it the hottest?

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1 Answer

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This question is a little tricky to answer.

Thermite refers to a specific pyrotechnic mixture, iron oxide and aluminum, but is also used to refer to whole class of reactions (“thermite reactions”) that are more generally called Goldschmidt reactions, for Hans Goldschmidt who recognized its value and studied it.

The original thermite, and thermites in general are unusual pyrotechnic reactions because they are condensed matter reactions that do not generally release gases. That “generally” part needs some explanation and is why this is a little tricky.

Thermite releases a lot of heat. Its products are molten aluminum oxide (usually thought of as a refractory) and molten iron at a temperature of 3135 K. Why this particular temperature? Because that is the boiling point of iron. Thermite releases so much heat it not only melts the iron produced, but boils some it away, cooling the mixture down (the boiling point of the aluminum oxide produced is just 115 K higher). If no phase changes occurred (melting the products, boiling some of the iron) the temperature produced would be 4382 K (if Fe_2O_3 is the oxide used).

Note that the boiling point of one of the reactants, aluminium, is only 2743 K so thorough mixing of the reactants is important to prevent part of the aluminum fuel from vaporizing.

This is typical of thermite reactions, which is a reaction between an element and the oxide of a different element. They usually produce so much heat that one or both reaction products melt, and one or more of them may boil. If they boil then they are releasing a gas, though in the case of regular thermite that gas is iron vapor.

So the temperature of a thermite reaction might be the calculated temperature from the reaction without phase changes, or with just the melting phase changes included (ignoring melting makes the temperature calculation sort of a theoretical fiction), or with the boiling included in which case the boiling temperature sets the final temperature. If the mixture is prevented from boiling (by packing it into a sealed container say, or running it under pressure) then the temperature is higher.

A convenient survey of these reaction is the Sandia National Laboratory report SAND95-2448C , “A Survey Of Combustible Metals, Thermites, And Intermetallics For Pyrotechnic Applications” is available from various sources on the Internet, but here is one:

http://losangelesgunstores.com/P...

In it we find the highest theoretical temperature (i.e. no phase changes) for any reaction listed is yttrium and I2O5 (iodine pentoxide) which is 12416 K. For the highest with phase changes (including air pressure boiling) is tantalum and I2O5, 7240 K, due to the high boiling point of tantalum oxide. Iodine pentoxide thermites are rarely prepared as the material is difficult to make and is not very stable.

Depending on the energy of the reaction and the properties of the products some thermites convert all of their product to gases, and can thus serve as a type of explosive. For example the tantalum thermite mentioned before produces tantalum oxide (and iodine) vapor as its product. Aluminum with silver oxide or lead oxide also produces metal vapor as its product (and vaporizes some of the aluminum oxide also). If conducted in air (the usual case) even more energy is released as the metal vapor reacts with oxygen to produce the oxide again.

The hottest thermite that has some physical residue (it doesn't *all* boil away) is thorium-lead oxide thermite since thorium oxide has an extremely high boiling point (4673 K).

The hottest thermite where *none* of it boils away is lanthanum - tungsten oxide thermite, which produces molten lanthanum oxide and tungsten metal at 4367 K.

The most energetic thermite reaction listed (cal/g) is magnesium and boron trioxide at 2134 cal/g making it as energetic as the super-explosive octanitrocubane. But the thermite is not an explosive because despite the great energy of the Mg + B2O3 reaction it produces little gas (some of the magnesium oxide boils away) due to the very high boiling points of the products. Its theoretical reaction temperature is 6389 K, its actual temperature with phase changes is 3873 K.

Here is a moron demonstrating lead thermite indoors:

Notice that cloud of lead oxide smoke on the ceiling? The OSHA and NIOSH Permissible Exposure Limit (PEL) for lead (for an 8 hour work day) is **50 µg**/m^3! And also notice he is not wearing a respirator.

Don't do this reaction at home, or at all.